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ABSTRACT

Preliminary work by Theresa McMillen and George Bodner has shown significant correlations between level of spatial visualization and orientation ability and success in a chemistry course designed for science and engineering majors. This study is an in-depth replication of McMillen's work with approximately 1600 science and engineering majors enrolled in a first semester general chemistry course and with about 800 students in a lower-level general chemistry course being examined. The latter course, designed for agriculture and nursing majors, was studied to determine whether spatial skills would be a more effective predictor of success in a chemistry course where lower levels of performance are expected, but also where student ability levels are generally lower. Sex differences in spatial ability and possible interactions between sex, spatial ability, and chemistry achievement were also examined. Among the findings are those showing that students with high spatial ability scores outperformed students with low spatial ability scores and that spatial ability is correlated with success in chemistry. Implications based on these and other findings for the teaching of science are discussed in relationship to recent data on the trainability of spatial skills. Eleven tables illustrating the results are included. (JN)

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SPATIAL ABILITY IN GENERAL CHEMISTRY

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SPATIAL ABILITY IN GENERAL CHEMISTRY

Most general chemistry curricula include some highly spatial topics, such as molecular geometry or crystal structure. However, it is not obvious that there should be any relationship between spatial skills and overall success in the typical freshman chemistry course simply because spatial topics are such a small fraction of the total course. When Bodner and McMillen began their spatial studies in general chemistry, they found significant positive correlations between scores on tests of spatial ability and success on crystal structure quizzes, as expected. They also found something that was not as easily explained: correlations between the spatial tests and success on problem-solving measures were as large as the correlations on "spatial" tasks. This study is (1) a replication of McMillen's work which looks at two divisions of a chemistry course for science and engineering majors (Chemistry 115) and (2) an extension of the project to a lower-level general chemistry course for agriculture and nursing majors (Chemistry 111).

We used four test instruments. One of these was the Purdue Visualization of Rotations test (Figure 1). This test measures the subject's ability to mentally manipulate the rotation of a two-dimensional representation of a three-dimensional figure. We used the rotations test because it is less likely than other spatial tests to be confounded by analytical processing, according to work done at Purdue. A second test, the Find a Shape Puzzle or FASP (Figure 2), is a measure of the

students' ability to disembed information from a complex visual field. Two filmed tests of lower-level spatial ability tasks, an embedded figures test and a successive figures test, were also administered.

Chemistry achievement was measured by the regular course hour exams and final exams, all written by the professors in charge of the courses. Subscores were formed by grouping similar questions taken from these examinations (Tables 1 and 2). This was done in an attempt to discover whether spatial ability was of greater importance in certain subject areas of chemistry such as stoichiometry or descriptive chemistry. We also wished to examine the relationships between spatial skills and particular types of questions, such as highly verbal questions or quantitative problems. Subscores covered such chemistry topics as stoichiometry, gas laws, crystal structure, descriptive chemistry, atomic structure, acid-base chemistry, etc. We also formed subscores of highly verbal questions and of quantitative questions.

We obtained data for approximately 1600 students in the upper-level course and 800 students in the non-science majors course. On the basis of their spatial scores, these students were classified as having high, medium or low spatial ability (Table 3). High spatial ability students were those scoring at least one-half standard deviation above the mean (for that course) on a given spatial test. Low spatial ability students scored at least one-half standard deviation below the mean. The remainder of students were classified as average spatial ability students. Since the means and standard deviations of each group

of students differ, a high spatial ability student in 111 does not necessarily have a spatial score comparable to that of a 115 student with high spatial ability.

We did analysis of variance using each spatial test individually and a combined spatial score. The literature and preliminary work by McMillen suggested that on the average males have higher spatial ability than females. For this reason we included sex as an independent variable in our study.

Analysis of variance gave some interesting results. In Chemistry 115 the Rotations test (Table 4), our measure of spatial reorientation, contributed significantly to all of the exams and quantitative subscores, except for one stoichiometry subscore in 115M. The FASP (Table 5), a measure of disembedding ability, also contributed to all measures except molecular geometry and acid-base-redox chemistry. Sex was a significant contributor to all measures in one division of the course, but showed no significance in the other division. In Chemistry 111 the Rotations score (Table 6) contributed significantly to every subscore except the one classified as general knowledge. The FASP contribution (Table 7) was significant in every subscore. Here, a male advantage was found in four of the subscores, all of which were problem-solving measures. On the other hand, a female advantage was found in the general knowledge subscore. In three of the fourteen subscores (Table 8) there was a significant interaction between sex and the total spatial score. No such interactions were found in the higher-level chemistry course.

Analysis of variance showed that significant differences in

chemistry achievement occurred with students of varying levels of spatial ability. Therefore we used a Scheffe's test to determine the actual direction of these differences. In Chemistry 115 (Table 9) these results showed that in general students with high spatial scores outperformed students of low spatial ability, particularly on problem-solving or quantitative tasks. In Chemistry 111, high-spatial ability students outperformed low-spatial ability students on all measures except the general knowledge subscore (Table 10).

Pearson's correlation coefficients showed a small, positive relationship between spatial ability and chemistry achievement on most subscores. In Chemistry 115 (Table 11) the significant correlations ranged from 0.071 to 0.25 for each measure, when considered individually. The Chemistry 111 correlations (Table 12) were of similar magnitude.

Multiple regression was used to complete the data analysis. Using the Rotations scores, FASP scores and sex as independent variables correlations ranged from 0.10 to 0.32 in Chemistry 115. In Chemistry 111 correlations ranged from 0.12 to 0.35. In 115 the Rotations score was the most highly significant variable in 10 of the 28 measures. In 12 of the measures the FASP was the most highly significant variable. Sex accounted for the greatest variance in two subscores. It is interesting to note that in 111 the Rotations test was the most significant variable in all but three subscores. The exceptions were the nonquantitative subscores general knowledge and gas concepts and the empirical formula subscore.

In the science and engineering majors course, Chemistry 115, SAT mathematics and verbal scores were used as covariates to control for level of mathematical and verbal skills. Using these factors as covariates slightly reduced the F ratio (Table 12) describing the relation between spatial ability and success, but spatial scores were still significant at the $p < 0.001$ level. This shows that even when mathematical and verbal ability are taken into account, spatial ability is still a factor in chemistry coursework. For the students in Chemistry 111 it is interesting to note that scores on the spatial tests were inter-correlated with SAT scores. Thus, it was not possible to do an analysis of covariance.

Evidence that spatial ability is correlated with success in chemistry and in other scientific and technical fields has implications for the way in which we teach chemistry. While further research is needed to determine the extent to which spatial ability training may influence achievement in chemistry, the literature indicates that spatial ability can be improved through training processes. This improvement may be accompanied by a higher level of achievement in chemistry. This research would seem to indicate that concepts in chemistry should be presented to the student in both a spatial, gestalt fashion as well as in a verbal, sequential manner. Students should be encouraged to build models, draw pictures, and represent verbal information graphically whenever possible. Encouraging students to represent all chemistry problems pictorially, even when this does not seem necessary to them, may aid their development of problem-solving

skills in several ways. First, this type of activity brings the problem down to a more concrete, manageable level. Second, this process should aid the students in developing the cognitive skills necessary in disembedding pertinent information from problem statements and in developing greater facility in the representation phase of the problem-solving process. In particular spatial ability training may lead to development of a greater awareness of non-verbal problem-solving strategies. This may further lead the student away from reliance upon rote memorization and toward meaningful learning in chemistry.

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FIGURE 1. SAMPLE ROTATIONS TEST ITEMS

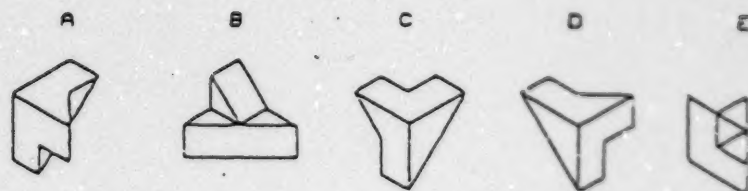
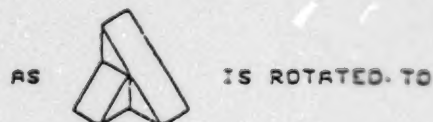
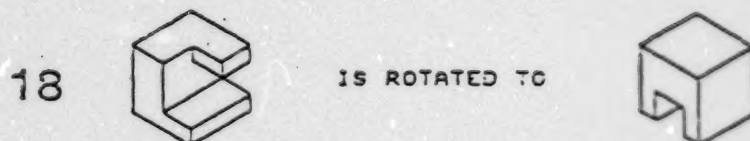
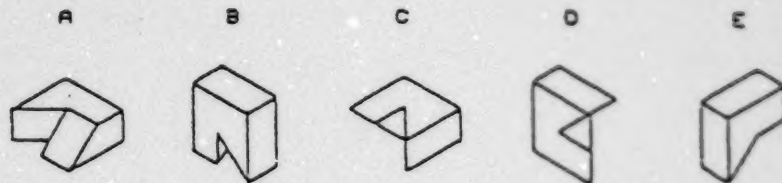
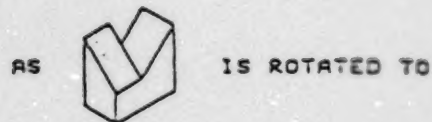
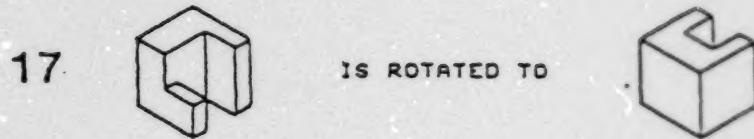
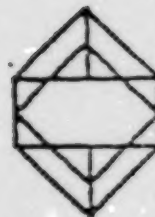
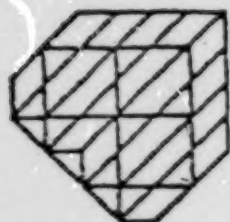
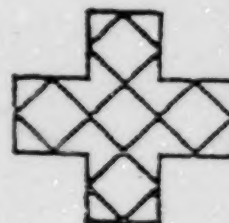
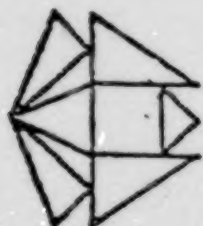


FIGURE 2. SAMPLE FASP ITEMS



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DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO.

TABLE 1. DESCRIPTION OF SUBSCORES FOR CHEMISTRY 115T

SUBSCR	DESCRIPTION
EXAM 1	First hour exam. 25 multiple choice questions.
EXAM 2	Second hour exam. 32 multiple choice questions.
EXAM 3	Third hour exam. 39 multiple choice questions.
FINAL	Two hour course final. 40 multiple choice questions.
SUB 1	Stoichiometry. 12 questions from exam one.
SUB 2	Gas quantative. 6 gas calculation problems from hour exam one.
SUB 3	Gas concepts. 4 concept-oriented (non-quantative) gas law problems from exam one.
SUB 4	Atomic structure/periodic properties. 12 questions from the second hour exam.
SUB 5	Geometry. 12 molecular geometry problems from the second hour exam.
SUB 6	Crystal structure. 11 crystal structure problems from the third hour exam and the final.
SUB 7	Verbal questions. 15 highly verbal questions from the third hour exam.
SUB 8	Thermodynamics. 7 enthalpy calculations from the third hour exam and the final.
SUB 9	Acid/base/oxidation/reduction. 6 problems from the third hour exam.
SUB 10	Descriptive. 13 questions on descriptive chemistry and chemistry content knowledge from the final exam.
SUB 11	Stoichiometry-final. 6 gas stoichiometry problems from the final exam.
SUB 12	Structure and periodic properties. 9 questions on atomic structure and periodic properties of the elements, taken from the final.

TABLE 2. SUBSCORES FOR CHEMISTRY 111

<u>SUBSCORE</u>	<u>DESCRIPTION</u>
A	Exam 1
B	Exam 2
C	Final
D	Stoichiometry 1: mass-mole calculations with Avogadro's number
E	Stoichiometry 2: balance chemical equations
F	Stoichiometry 3: gram-mole calculations
G	Stoichiometry 4: empirical formulas
H	Stoichiometry 5: sub d + sub e + sub g
I	Factor Label
J	General Knowledge
K	Chemical Knowledge
L	Verbal
M	Gas Law Calculations
N	Gas Law- Non-calculations

TABLE 3. SPATIAL EXAM SCORES

	Mean	St. Dev.	Low	Med	H1
<u>Chemistry 111</u> ROTATIONS	11.692	3.933	0-10.73	10.73-13.66	13.66+
FASP	11.745	5.188	0-9.25	9.25-14.34	14.34+
<u>Chemistry 115</u> ROTATIONS	13.960	3.795	0-12.06	12.06-15.86	15.86+
FASP	13.864	3.887	0-11.92	11.92-15.81	15.81+

TABLE 4: CHEMISTRY 115T ANOVA RESULTS FOR ROTATIONS SCORES

<u>SUBSCORE</u>	<u>N</u>	<u>SOURCE</u>	<u>F VALUE</u>	<u>SIG OF F</u>
Exam 1	631	ROT	11.817	.001***
		Sex	0.061	.804
Exam 2	575	ROT	4.741	.009**
		Sex	0.838	.360
Exam 3	569	ROT	7.100	.009**
		Sex	0.117	.732
Final	561	ROT	8.203	.001***
		Sex	0.737	.391
Subscr 1 (Stoichiometry)	631	ROT	11.817	.001***
		Sex	0.527	.468
Subscr 2 (Gas _ quant)	631	ROT	8.892	.001***
		Sex	0.009	.923
Subscr 3 (Gas _ concepts)	631	ROT	2.089	.125
		Sex	0.001	.971
Subscr 4 (Atomic str.)	575	POT	4.900	.008**
		Sex	0.257	.612
Subscr 5 (Geometry)	575	Rot	4.197	.016*
		Sex	0.120	.729
Subscr 6 (Crystal str.)	575	ROT	7.162	.001***
		Sex	0.292	.589
Subscr 7 (Verbal quest.)	557	ROT	1.547	.214
		Sex	0.000	.986
Subscr 8 (Thermodynamics)	557	ROT	7.369	.001***
		Sex	0.274	.601
Subscr 9 (Acid/Base/Redox)	557	ROT	1.106	.332
		Sex	0.358	.550
Subscr 10 (Descriptive)	557	ROT	1.927	.147
		Sex	0.358	.550
Subscr 11 (Stoichiometry)	557	ROT	7.079	.001***
		Sex	1.225	.269
Subscr 12 (Str./per. prop.)	557	ROT	3.794	.023*
		Sex	0.565	.452

TABLE 5: CHEMISTRY 115T ANOVA RESULTS FOR FASP

<u>SUBSCORE</u>	<u>N</u>	<u>SOURCE</u>	<u>F</u> <u>VALUE</u>	<u>SIG</u> <u>OF F</u>
Exam 1	631	ROT	8.237	.001***
		Sex	2.681	.102
Exam 2	575	ROT	4.349	.013*
		Sex	2.902	.089
Exam 3	569	ROT	7.869	.001***
		Sex	1.830	.177
Final	561	ROT	9.543	.001***
		Sex	3.413	.065
Subscr 1 (Stoichiometry)	631	FASP	5.084	.006**
		Sex	4.284	.039*
Subscr 2 (Gas - quant)	631	FASP	7.415	.001***
		Sex	1.651	.199
Subscr 3 (Gas - concepts)	631	FASP	3.729	.025*
		Sex	0.874	.530
Subscr 4 (Atomic str.)	575	FASP	3.012	.050*
		Sex	1.640	.201
Subscr 5 (Geometry)	575	FASP	0.912	.402
		Sex	1.640	.201
Subscr 6 (Crystal str.)	575	FASP	6.455	.002**
		Sex	2.226	.136
Subscr 7 (Verbal quest.)	557	FASP	3.633	.027*
		Sex	0.185	.667
Subscr 8 (Thermodynamics)	557	FASP	7.325	.001***
		Sex	2.344	.126
Subscr 9 (Acid/Base/Redox)	557	FASP	2.171	.115
		Sex	0.056	.814
Subscr 10 (Descriptive)	557	FASP	4.249	.015*
		Sex	1.106	.293
Subscr 11 (Stoichiometry)	557	FASP	8.710	.001***
		Sex	3.998	.046*
Subscr 12 (Str./per. prop.)	557	FASP	5.009	.007**
		Sex	2.002	.158

TABLE 6: CHEMISTRY 111 ANOVA RESULTS FOR ROTATIONS SCORES

<u>SUBSCORE</u>	<u>SOURCE</u>	<u>F VALUE</u>
Exam1	Main Effects	12.624*
	Sex	6.191*
	ROT	18.766*
	Sex x ROT	1.040
Exam2	Main Effects	7.570*
	Sex	.068
	ROT	10.576*
	Sex x ROT	.391
Final	Main Effects	16.836*
	Sex	.400
	ROT	24.087*
	Sex x ROT	.501
Subscr D	Main Effects	12.041*
	Sex	6.313*
	ROT	9.730*
	Sex x ROT	1.159
Subscr E	Main Effects	10.156*
	Sex	.645
	ROT	14.864*
	Sex x ROT	1.067
Subscr F	Main Effects	8.702*
	Sex	2.222
	ROT	13.051*
	Sex x ROT	.039
Subscr G	Main Effects	8.306*
	Sex	4.661*
	ROT	6.732*
	Sex x ROT	1.221
Subscr H	Main Effects	15.981*
	Sex	3.825*
	ROT	16.276*
	Sex x ROT	1.258
Subscr I	Main Effects	23.298*
	Sex	2.953
	ROT	26.394*
	Sex x ROT	.581
Subscr J	Main Effects	3.039*
	Sex	7.886*
	ROT	1.870
	Sex x ROT	.238

TABLE 6 (continued)

Subscr K	Main Effects	4.559*
	Sex	.865
	ROT	6.819*
	Sex x ROT	.594
Subscr L	Main Effects	10.281*
	Sex	.110
	ROT	14.511*
	Sex x ROT	1.816
Subscr M	Main Effects	11.882*
	Sex	.346
	ROT	17.029*
	Sex x ROT	.413
Subscr N	Main Effects	6.100*
	Sex	1.048
	ROT	9.122*
	Sex x ROT	.412

*: significant at or below the .05 level

TABLE 7: CHEMISTRY 111 ANOVA RESULTS FOR FASP SCORES

<u>SUBSCORE</u>	<u>SOURCE</u>	<u>F VALUE</u>
Exam1	Main Effects	8.118*
	Sex	.413
	FASP	12.011*
	Sex x FASP	.535
Exam2	Main Effects	10.558*
	Sex	1.342
	FASP	15.048*
	Sex x FASP	1.207
Final	Main Effects	15.241*
	Sex	2.102
	FASP	21.704*
	Sex x FASP	.304
Subscr D	Main Effects	11.732*
	Sex	16.324*
	FASP	9.266*
	Sex x FASP	1.638
Subscr E	Main Effects	5.904*
	Sex	.356
	FASP	8.491*
	Sex x FASP	.924
Subscr F	Main Effects	5.543*
	Sex	.000
	FASP	8.312*
	Sex x FASP	.051
Subscr G	Main Effects	10.810*
	Sex	11.270*
	FASP	10.446*
	Sex x FASP	.235
Subscr H	Main Effects	15.937*
	Sex	14.962*
	FASP	16.211*
	Sex x FASP	1.255
Subscr I	Main Effects	22.222*
	Sex	16.594*
	FASP	24.802*
	Sex x FASP	1.162
Subscr J	Main Effects	2.994*
	Sex	5.449*
	FASP	1.800
	Sex x FASP	.574

TABLE 7 (continued)

Subscr K	Main Effects	3.749*
	Sex	.029
	FASP	5.604*
	Sex x FASP	.310
Subscr L	Main Effects	5.923*
	Sex	1.698
	FASP	7.994*
	Sex x FASP	.196
Subscr M	Main Effects	9.558*
	Sex	1.418
	FASP	13.552*
	Sex x FASP	.198
Subscr N	Main Effects	5.006*
	Sex	.044
	FASP	7.481*
	Sex x FASP	.205

*: significant at or below the .05 level

TABLE 8: CHEMISTRY 111 ANOVA RESULTS FOR SPAT SCORES

<u>SUBSCORE</u>	<u>SOURCE</u>	<u>F VALUE</u>
Exam 1	Main Effects	11.233*
	Sex	.340
	Spat	16.679*
	Sex x Spat	2.804
Exam 2	Main Effects	13.624*
	Sex	1.604
	Spat	19.635*
	Sex x Spat	2.672
Final	Main Effects	19.237*
	Sex	2.353
	Spat	27.679*
	Sex x Spat	.461
Subscr D	Main Effects	14.283*
	Sex	16.943*
	Spat	12.953*
	Sex x Spat	4.202*
Subscr E	Main Effects	9.682*
	Sex	.742
	Spat	12.944*
	Sex x Spat	2.565
Subscr F	Main Effects	8.631*
	Sex	.004
	Spat	12.944*
	Sex x Spat	.236
Subscr G	Main Effects	13.499*
	Sex	11.789*
	Spat	14.354*
	Sex x Spat	4.454*
Subscr H	Main Effects	20.207*
	Sex	13.834*
	Spat	22.393*
	Sex x Spat	6.062*
Subscr I	Main Effects	28.425*
	Sex	17.541*
	Spat	33.681*
	Sex x Spat	2.392
Subscr J	Main Effects	3.218*
	Sex	5.394*
	Spat	2.130
	Sex x Spat	1.046

TABLE 8 (continued)

Subscr K	Main Effects	4.748*
	Sex	.040
	Spat	7.102*
	Sex x Spat	.714
Subscr L	Main Effects	9.767*
	Sex	1.814
	Spat	13.744*
	Sex x Spat	1.165
Subscr M	Main Effects	13.338*
	Sex	1.595
	Spat	19.209*
	Sex x Spat	.323
Subscr N	Main Effects	5.999*
	Sex	.056
	Spat	8.971*
	Sex x Spat	.070

*: significant at or below the .05 level

TABLE 9: SCHEFFE'S TEST 115T LOW(1), MIDDLE(2) AND HIGH(3)
SPATIAL STUDENTS

<u>Subscr</u>	<u>Source</u>	<u>Mean(1)</u>	<u>Mean(2)</u>	<u>Mean(3)</u>
Exam 1	TSPAT	12.954(1)	14.390(2)	15.018(3)
	ROT	12.833(1)	14.255(2)	15.004(3)
	FASP	13.257(1)	14.116(2) 14.116(2)	14.901(3)
Exam 2	TSPAT	20.497(1)	21.049(2) 21.049(2)	21.927(3)
	ROT	20.131(1)	21.239(2) 21.239(2)	21.807(3)
	FASP	20.634(1)	20.752(2)	21.818(3)
Exam 3	TSPAT	21.667(1)	22.320(2)	23.818(3)
	ROT	21.303(1)	22.637(2) 22.637(2)	23.516(3)
	FASP	21.735(1)	22.192(2)	23.517(3)
Final	TSPAT	15.489(1)	17.692(2)	18.600(3)
	ROT	15.777(1)	17.518(2)	18.309(3)
	FASP	15.820(1)	17.811(2)	18.276(3)
Sub 1	TSPAT	6.333(1)	7.228(2)	7.620(3)
	ROT	6.312(1)	7.187(2)	7.525(3)
	FASP	6.691(1)	7.097(2) 7.097(2)	7.487(3)

TABLE 9 (continued)

Sub 2	TSPAT	3.399(1)	3.925(2)	4.082(3)
	ROT	3.449(1)	3.813(2)	4.099(3)
	FASP	3.537(1)	3.842(2)	4.079(3)
Sub 3	TSPAT	1.471(1)	1.660(2)	1.761(3)
	ROT	1.507(1)	1.653(2)	1.711(3)
	FASP	1.474(1)	1.671(2)	1.746(3)
Sub 4	TSPAT	9.737(1)	9.791(2)	10.230(3)
	ROT	9.451(1)	9.991(2)	10.981(3)
	FASP	9.765(1)	9.792(2)	10.130(3)
Sub 5	TSPAT	3.962(1)	4.149(2)	4.362(3)
	ROT	3.869(1)	4.183(2)	4.323(3)
	FASP	4.059(1)	4.184(2)	4.237(3)
Sub 6	TSPAT	4.155(1)	4.663(2)	5.271(3)
	ROT	4.108(1)	4.766(2)	5.037(3)
	FASP	4.196(1)	4.795(2)	5.048(3)
Sub 7	TSPAT	9.217(1)	9.481(2)	9.729(3)
	ROT	9.200(1)	9.528(2)	9.626(3)
	FASP	9.135(1)	9.590(2)	9.660(3)

TABLE 9 (continued)

Sub 8	TSPAT	3.225(1)	3.550(2) 3.550(2)	3.835(3)
	ROT	3.175(1)	3.541(2) 3.541(2)	3.795(3)
	FASP	3.311(1)	3.460(2)	3.874(3)
Sub 9	TSPAT	3.357(1)	3.504(2)	3.682(3)
	ROT	3.383(1)	3.486(2)	3.639(3)
	FASP	3.410(2)	3.486(1)	3.639(3)
Sub 10	TSPAT	3.789(1)	4.143(2) 4.143(2)	4.453(3)
	ROT	3.833(1)	4.188(2)	4.506(3)
	FASP	3.764(1)	4.255(2) 4.255(2)	4.345(3)
Sub 11	TSPAT	6.899(1)	7.762(2)	7.941(3)
	ROT	7.000(1)	7.651(2)	7.918(3)
	FASP	7.034(1)	7.725(2)	7.923(3)
Sub 12	TSPAT	5.791(1)	6.485(2)	6.877(3)
	ROT	5.975(1)	6.473(2) 6.473(2)	6.671(3)
	FASP	5.946(1)	6.540(2) 6.540(2)	6.703(3)

TABLE 10: CHEMISTRY 111 SCHEFFE'S TEST RESULTS

<u>SUBSCORE</u>	<u>SOURCE</u>	<u>MEAN(1)</u>	<u>MEAN(2)</u>	<u>MEAN(3)</u>
Exam 1	ROT	20.472(1)	21.752(2)	22.473(3)
	FASP	20.654(1)	21.791(2)	22.390(3)
	SPAT	20.466(1)	21.670(2)	22.609(3)
Exam 2	ROT	16.496(1)	17.687(2)	18.446(3)
	FASP	16.713(1)	17.186(2)	18.728(3)
	SPAT	16.450(1)	17.264(2)	19.080(3)
Final	ROT	30.690(1)	34.041(2)	35.698(3)
	FASP	31.551(1)	33.104(2)	36.011(3)
	SPAT	30.640(1)	33.713(2)	36.308(3)
Sub D	ROT	4.578(1)	4.870(2)	5.515(3)
	FASP	4.681(1)	4.907(2)	5.396(3)
	SPAT	4.616(1)	4.828(2)	5.605(3)
Sub E	ROT	3.876(1)	4.283(2)	4.462(3)
	FASP	4.028(1)	4.144(2)	4.473(3)
	SPAT	3.863(1)	4.269(2)	4.502(3)

TABLE 10 (continued)

Sub F	ROT	2.262(1)	2.598(2)	2.786(3)
	FASP	2.418(1)	2.451(2)	2.789(3)
	SPAT	2.303(1)	2.532(2)	2.846(3)
Sub G	ROT	3.817(1)	4.195(2)	4.355(3)
	FASP	3.904(1)	4.084(2)	4.400(3)
	SPAT	3.758(1)	4.148(2)	4.476(3)
Sub H	ROT	12.271(1)	13.349(2)	14.332(3)
	FASP	12.614(1)	13.135(2)	14.269(3)
	SPAT	12.237(1)	13.246(2)	14.584(3)
Sub I	ROT	6.959(1)	7.897(2)	8.553(3)
	FASP	7.183(1)	7.777(2)	8.824(3)
	SPAT	6.967(1)	7.758(2)	8.777(3)
Sub K	ROT	8.473(1)	8.943(2)	9.233(3)
	FASP	8.578(1)	8.847(2)	9.233(3)
	SPAT	8.493(1)	8.875(2)	9.322(3)

TABLE 10 (continued)

Sub L	ROT	6.367(1)	7.023(2)	7.366(3)
	FASP	6.598(1)	6.916(2) 6.916(2)	7.302(3)
	SPAT	6.398(1)	6.963(2)	7.438(3)
Sub M	ROT	4.273(1)	5.086(2)	5.576(3)
	FASP	4.553(1)	4.189(2)	5.614(3)
	SPAT	4.261(1)	5.023(2)	5.714(3)
Sub N	ROT	3.505(1)	3.832(2)	3.937(3)
	FASP	3.557(1)	3.796(2) 3.796(2)	3.954(3)
	SPAT	3.502(1)	3.812(2)	3.971(3)

(1): low (2): middle (3): high

TABLE 11. PEARSON CORRELATION COEFFICIENTS-- CHEM115

CHEM 115M			CHEM 115T		
<u>SUBSCR</u>	<u>ROT</u>	<u>FASP</u>	<u>SUBSCR</u>	<u>ROT</u>	<u>FASP</u>
Exam 1	.246***	.226***	Exam 1	.161***	.167***
Exam 2	.157***	.216***	Exam 2	.125***	.072*
Exam 3	.174***	.209***	Exam 3	.146***	.121**
Final	.170***	.182***	Final	.190***	.172***
Sub 1	.088*	.131**	Sub 1	.169***	.144***
Sub 2	.222***	.203***	Sub 2	.138***	.153***
Sub 3	.216***	.173***	Sub 3	.053	.093*
Sub 4	.229***	.232***	Sub 4	.136***	.049
Sub 5	.070	.130**	Sub 5	.119**	.054
Sub 6	.190***	.168***	Sub 6	.071*	.099*
Sub 7	.113**	.163***	Sub 7	.170***	.146***
Sub 8	.122**	.151***	Sub 8	.145***	.111**
Sub 9	.118**	.116**	Sub 9	.064	.046
Sub 10	.079*	.143***	Sub 10	.101**	.114***
Sub 11	.155***	.215***	Sub 11	.159***	.146***
Sub 12	.134**	.184***	Sub 12	.139***	.128***

TABLE 12. PEARSON CORRELATION COEFFICIENTS-- CHEM 111

<u>SUBSCORE</u>	<u>ROTATIONS</u>	<u>FASP</u>
Exam 1	.1962***	.2026***
Exam 2	.1729***	.1887***
Final	.2487***	.2361***
Subscr D	.1957***	.1555***
Subscr E	.1847***	.1500***
Subscr F	.1765***	.1334***
Subscr G	.1642***	.1613***
Subscr H	.2388***	.2024***
Subscr I	.2865***	.2024***
Subscr J	.0422	.0730*
Subscr K	.1301***	.1228***
Subscr L	.1990***	.1488***
Subscr M	.2137***	.1854***
Subscr N	.1464***	.1431***
SATM	.3173***	.3328***
SATV	.0801**	.1720***

* : sign. at or below .05 level

** : sign. at or below .01 level

*** : sign. at or below .001 level